Biological and Physical Research Advisory Committee (BPRAC) Minutes
NASA Headquarters
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Kenneth Baldwin
Dr. Kenneth Baldwin, Chair

Louis Ostrach
Dr. Louis Ostrach, Executive Secretary

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Report prepared by:
Joan M. Zimmermann
Consultant, Infonetic

Welcome/Chair's Review of Agenda/Logistics

Dr. Kenneth Baldwin, Chairman of the Biological and Physical Research Advisory Committee (BPRAC), welcomed members and opened the meeting. Dr. Louis Ostrach, NASA HQ, was introduced as the new Executive Secretary of the BPRAC. Members of the committee introduced themselves. New to the BPRAC were Dr. Richard Lahey, Dr. Tim Anderson, Ms. Linda Billings, Mr. Stephen Day and Dr. Amy Kronenberg.

Ethics Presentation

Ms. Rebecca Gilchrist, Code GG ethics attorney, presented the annual ethics review for Special Government Employees (SGEs) serving on NASA Advisory Committees. The definition of an SGE was given as anyone designated, appointed, or employed to perform temporary duties, with or without compensation, for a period of up to 130 days out of any 365 days, and includes participants in advisory committees. SGEs are subject to the same rules as other civil servants, such as proper standards of conduct, admonition to avoid conflicts of interest, prohibition on disclosure of nonpublic information and the avoidance of the appearance of impropriety. SGEs must also file a "450" form (a confidential financial report) each year. Ethics principles were reviewed. The status of the SGE is equivalent to being an insider, and the SGE is therefore subject to civil service ethics rules.

SGEs are also subject to post-employment restrictions. Under these restrictions, representational conflicts under US criminal code 18 prohibit representational activities before the Government (taking an official action that has a direct and predictable effect on the SGE's interest, or spouse, dependent child, or commercial concern). This applies to SGEs only if the matter involves parties (e.g., contracts), if the SGE was personally and substantially involved in the particular matter (such as a particular contract) as part of Government service, and the SGE has served more than 60 days in the previous 365.

The financial conflict code prohibits SGE involvement in a particular matter in which the SGE, employer, or spouse or dependent child has a financial interest. An example of a potential conflict is possessing stock in Boeing Corporation. Members were reminded to recuse themselves from a discussion if they find themselves in an area of potential conflict. The Executive Secretary was recognized as a good source of advice on these matters. There is an official threshold amount (15K aggregate total of the companies of interest) of financial interest beyond which an SGE must not possess. "Sector funds", a mutual fund subset, are subject to special scrutiny if they fall into NASA-related interests such as aeronautics. Form 278 is a public form, subject to FOIA regulations; 450 forms, however, are kept confidential.

Post-employment restrictions permanently prohibit an employee from making any communication to the US on behalf of any other person, in connection with matters in the US, if the employee was personally involved. Standards of conduct include restriction on gifts, unless the gifting occurs outside business activities, within personal relationships, or if the value of the gift falls under the $20/$50 rule (under $20 per gift, for no more than $50 in any year for one source). If a member has a question, he or she can call the Designated Agency Ethics Official (DAEO) Paul Pastorek, Andrew Falcon, Ms. Gilchrist, or Katie Spear (contact information provided in the distributed literature). Elaboration was requested on post-employment restrictions. Members were advised to contact the DAEO team upon leaving the committee in order to clear up any questions on specific contracts. Recommendations on policy that might affect research programs or institutions, if specific enough (i.e., working with a

particular institute) are subject to prohibition, however broad matters of policy recommendations would not constitute a conflict of interest.

Review of BPRAC Recommendations

Dr. Louis Ostrach reviewed previous recommendations of the BRPRAC.

- The Free Flyer Initiative has been strongly endorsed and NASA is examining existing Free Flyers under the current budget process. Progress on the Free Flyer Initiative will be reported on routinely.

- De-prioritized Investigative Teams will develop a transition plan that accounts for the impact on the affected scientific community. Dr. Howard Ross will address this topic later in the meeting.

- The Enterprise should develop an advisory subcommittee structure plan that envisions task forces, ad hoc committees, etc. to address issues on an as-needed basis. Ms.. Mary Kicza will address this later in the meeting.

- Dr. Baldwin commented that presentations had been requested on specific topics to learn about NASA's new order, and was pleased to see that these are in the current agenda.

OBPR Program Review

Ms. Mary Kicza, Associate Administrator for the Office of Biological and Physical Research (OBPR), provided an overview of the activities of the enterprise. The team has been very busy, but there is much progress yet to be made.

Efforts to align with the new vision for US Space Exploration include refinement of the Bioastronautics Critical Path Roadmap (CPR), a construct intended to focus research on prevention, reduction and elimination of risk to humans during space flight and increase the efficiencies of systems supporting humans in space. Current activities include assessing risks in light of the new vision; an updated draft of the CPR was submitted to an unprecedented independent review by the National Research Council in April 2004, with feedback expected in September 2004. OBPR is reassessing countermeasure validation requirements and strategies, has held a Human Subjects Strategy Workshop (May 12-13 at Johnson Space Center), and will conduct a Review with the Astronaut Office and Flight Surgeons (planned for May 25-26). The results of these endeavors will be incorporated into the CPR.

Accepted risk criteria must be defined; initial areas being addressed are bone and renal health, and radiation effects. Potential mechanisms to stabilize funding to external research community are being investigated, and these include how to use ground-based and flight opportunities. Throughout the FY06 budget development effort, OBPR has adjusted the research portfolio to meet the exploration agenda within the planned budget. Associate Administrators (AAs) are meeting across the codes to effect the alignment. OBPR is working closely with the Office of Space Flight and the International Space Station (ISS) and is considering Free Flyer opportunities. OBPR is also establishing relationships with the Office of Space Science, Office of Exploration Systems, the Joint Strategic Assessment Committee (JSAC) and the Exploration Science Working Group (ESWG). Projects that

are not aligned with the vision have been identified and accordingly OBPR has developed a product line framework for meeting vision needs. A full day review with Research Partnership Centers (RPCs) was conducted on April 7, 2004, with the Office of Exploration Systems' participation, to identify where RPCs align with the product line framework. Dr. Baldwin asked if there were any fall-back plans in place to accommodate any changes that might result from the November election. Ms. Kicza replied that there is support for the vision, but movement on the budget decisions will be stalled until the election is over. However, OBPR will be in a good position to move forward with the vision, in any case. Dr. Baldwin remarked that even in the best scenario, there is disharmony in the Republican party for support of the new exploration vision. Ms. Kicza maintained that OBPR is sustaining a fundamental base for the next generation of support for a long-term vision. Dr. Baldwin rephrased OBPR's stance as having an offensive game plan, prepared to audibilize at the line of scrimmage. Ms. Kicza concurred with this assessment.

Code U areas of emphasis for alignment with the new vision have been spotlighted: radiation health effects, loss of bone density and muscle strength, behavioral health, and trauma (injury and illness). Technology development areas include real time medical diagnosis, human habitability technologies, and research to support low-mass, low-volume reliable exploration systems. OBPR recognizes the need to seed future endeavors and communicate the importance of OBPR's work in delivering benefits to Earth. A recent (February 2004) Tucson, AZ workshop with the field centers led to recommendations that discouraged total reorganization. Dr. Duke asked: what is the process for developing reliable exploration systems? What is the decision process behind deciding on research projects for Code U, as distinct from what drives Code T? Ms Kicza responded that Code U is in a continuing dialogue with Code T and there is an ongoing relationship with them in determining work that can be done in concert.

Aligning with the vision necessitates transitioning to product lines that were delineated by three key areas, to be elaborated in a later presentation. The one or two long poles were radiation, and behavior and performance. Bone density and muscle strength studies are being addressed on ISS. Closed-loop life support is another area of major concern. Dr. Kronenberg asked about basic underpinnings of research on radiation. Ms. Kicza noted that there will be basic research consistent with what Code U is already doing and that radiation is a key area of concern. Implications for ISS include actually performing the research and validating the countermeasures. The ISS-based exploration program will be comprised of research, development and demonstration. Dr. Baldwin observed that there has been a lot of chatter that undermines the support for ISS- will there be future support from the budget? Ms. Kicza replied that the Office of Management and Budget (OMB), the Hill, and senior management support the ISS agenda, but OBPR plans must be sensitive to return to flight (RTF) and Shuttle retirement, and use this knowledge to inform research plans on ISS. RD&D will address red risks on ISS, as identified by the CPR. Draft Human Health and Countermeasures, Autonomous Medical Care and Behavioral Health and Performance were briefly presented. OBPR is considering scenarios with a larger crew (with increased use of Russian assets) earlier rather than later. Types of projects/products for ISS are performance of Sabatier reactors, validation of system stability, flammability of materials, rapid prototyping for fabrication of spare parts for long-distance missions, experimental demonstration of granular media for particulate control, microbial technology for water recycling methods, methods for oxygen generation, and demonstration of zero-gravity fabrication of useful tools from regolith simulants. Dr. Charles Fuller commented on growing rumors about revisiting the candidate atmosphere debate; the fire safety groups are concerned and want to hear about this. Ms. Kicza replied that an

internal brief is being prepared on this matter. Dr. Gerard Faeth noted this is a cross-disciplinary area that will set up the atmosphere that humans will use from this point forward, therefore it is imperative to understand physiological impacts and fire hazards of the selected atmosphere. It must not get lost in shuffle; it is the biggest deal on the agenda. Dr. Lahey commented OBPR priorities appear to be biological rather than physical; recent workshops have laid out what it will take to reliably use atmosphere generation methods; is someone else handling this stuff (validation of system stability)? Ms. Kicza agreed that it is a cross-enterprise activity- OBPR is starting to make the connections for developing space suits with Code T, for example. Dr. Eugenia Wang commented that it is good to look at each system in its separate category, but an integrated approach is also necessary- given the technology advances we now have; is there an existing product that is in the pipeline to be used as a specific example in the roadmap? What would the Food and Drug Administration (FDA) think, for example, about early products or the NIEH (National Institute of Environmental Health)? Ms. Kicza replied that OBPR is waiting for RTF, which is why there is not too much product on the "left side" in the near term. We know there is a lot of work going on to model elements of the human as a system; we know we are collectively working toward an integrated system in a given environment.

The OBPR decision map will be guided by benefit assessments vs. cost assessments, with weighting factors such as strategic value, critical risk, relevance to or a driver for Exploration, basis for research content, terrestrial benefits, and ISS resources required. Ms. Kicza would like members of the BPRAC to deliver comments to Dr. Howard Ross. Dr. Ross commented that a sample problem is that OBPR has some experiments ready to fly, but limited upmass capacity and would like to obtain advice on which experiments should be sent up. The decision will not be purely quantitative. Dr. Mary Musgrave asked if this implies that only bioastronautics experiments will fly. Ms. Kicza replied that the emphasis is on human health on ISS, emphasizing human health and countermeasures consistent with the Presidential directive.

In summary, Code U has been aggressively pursuing alignment, broadcasting materials for public comment, and exploring ways to engage the research community and other NASA enterprises in this process. OBPR is working closely with the Office of Space Flight to address requirements for Exploration, in light of capacity considerations. Dr. Borer commented that this is the best overarching strategic vision he had ever seen from Code U; it has a crystal-clear focus. There is an institutionalized plan to communicate outside the code; it is outstanding. Dr. Wang observed that current conditions in OBPR reminded her of the early stages of the Human Genome Project and its political implications; it takes some great leadership and the ability to ignore political chatter to begin a large enterprise. Dr. Baldwin commented that in dividing up the assignments within OBPR, although it is skewed to human presence in space in order to create the deliverables, there is a broad set of tasks to be achieved. He felt that time was of the essence, and the sooner OBPR determines who is going to execute the plan, the easier it will be to begin. Ms Kicza recognized that OBPR must apply all the competencies in its program to achieve its goal. Timelines on such matters as critical atmosphere decisions will be dealt with in the presentation of Level 1 requirements and how these affect the timeline. Ms. Kicza took an action on atmospheric pressure issues and oxygen concentrations.

OBPR Exploration Product Lines

Mr. Bernard Seery presented particulars of the Code U product line management approach, addressing relationships between the organizing questions behind the exploration initiative:

- How can we assure survival of humans traveling far from Earth?
- How does life respond to gravity and space environments?
- What new opportunities can research bring to expand understanding of the laws of Nature and enrich life on Earth?
- What technology must we create to enable the next explorers to go beyond where we have been?

The product line is the programmatic framework for OBPR. The rationale behind the Work Breakdown Structure (WBS) is the process that relates the elements of work to be accomplished to each other and to the end product. WBS helps to align the research program with other aspects of the Exploration Systems development, which in turn is related to the Technology Readiness Level (TRL). The nine levels of the NASA TRL system were defined, from one (basis principles observed and reported) through 9 (actual system "flight-proven" through successful mission operations). Code U operates at around the TRL 1 and 2 levels. Dr. Duke asked: how does TRL relate to human-related technology? Isn't code U responsible from end to end? Ms. Kicza replied that in the human arena as it relates to countermeasures, Code uses a countermeasure readiness level scale (CRL); however use of such technology is carried through the Office of Medical Operations. Dr. Wang commented that an FDA TRL 9 takes 20 years- how long does NASA take? Mr. Seery replied that it depends on the hardware. A nuclear fuel component may take 10 years; moreover, not everything matures to the TRL 9 level- if the research is focused, the R&D effort moves forward rapidly. If not, the progress is slower.

Large focused design and development efforts warrant the WBS framework; it also lends itself well to building a historical database, defining a program structure, and building toward an earned value management system (EVMS). The project work breakdown structure was graphically presented, demonstrating how subsystems are integrated into major systems. These were both discipline- and product-based. There must be clear lines of authority, and the project structure must be manageable, independent and integratable, as well as measurable. It forms the basis of network scheduling, costing, risk analysis, project controls and management, and coordination of objectives. The WBS is actually separate from the organization itself. The benchmark for success is on-time delivery with zero variance analysis (i.e., the project comes in at or under cost). OBPR Product Line managers are divided into the Human Support System, Radiation Protection, Human Health and Performance, Life in Moon/Mars and Deep Space Environment, Flight Systems, Advanced Concepts and Technology Maturation, and Partnership, Education and Outreach. Ms Kicza reminded the BPRAC to bare in mind there is much cross-talk among the leaders of the product lines. This is a structure in progress. Dr. Duke asked if Code U believed it had an important role to play for future research in space, adding that he saw an absence of a manager for this role. Ms. Kicza replied that each product line has a fundamental research component, and leaders have been asked to identify what the component should be. Dr. Duke commented that advanced materials, such as for nuclear aspects, is a product line that should be present. The Code U response was that the human/robotic division has materials and structures that will be developing advanced materials for multiple applications. Dr. Lahey noted the absence of power, propulsion, and reprocessing, and development of nuclear reactor power conversion techniques, and asked which code was responsible for such research and development. Gary Lyles (Code T) was identified as someone who could answer this question. Dr. Kronenberg observed that "radiation

protection" is a misnomer- it has an operational meaning in the outside community- what is lost is the "radiation health and risk analysis" as a human health and performance issue. Radiation protection also extends to electronics. Dr. Borer added that there has not been an emphasis on developing materials for these products; Code U isn't going to do this; (interdisciplinary) communications must be made at an early stage and must be institutionalized. Ms. Kicza remarked that as OBPR gets into the details, it can in fact communicate and be able to hand off efforts as they progress. The human/robotic code has its own organization and is appointing team members in cross-pollinating groups across the enterprises. Code U is educating Code T on what radiation health is and how it impacts the design of systems. Dr. Wang noted that the sooner the product people in codes U and T were integrated, the sooner one would have a pyramidal effect on the product; in addition, there needs to be an education process to resolve the gap between cultures.

OBPR content analysis was performed by the Wilcoxon team, which established a hierarchical set of definitions to ensure levels 1-5 in product development. Level 4 is where one would begin to see the fundamental research component (due on May 27). Dr. Fuller remarked that in the case of fundamental research, R&D is always the reservoir chosen to resolve overruns- how does it get protected from budget vagaries? Mr. Seery replied that the products are what are owed to other customers; Work Breakdown Structure Level 4 keeps fundamental research at the cost level. Dr. Borer commented that one of the issues is to assure that the proof-of-concept based on fundamental research isn't picked up as a basis for application prematurely. It is important to ensure that the putative results of the fundamental research are not applied before they are ready. Mr. Seery pointed out that the paradigm is geared to milestone delivery. Dr. Borer cited the need to have a reasonably good idea of how much research needs to be done for a given deliverable; this needs to be monitored. Dr. Tim Anderson observed that the product line approach helps work move forward independent of the structure of the organization (central vs. disseminated). A lot of the concern is about what the R&D model is going to be. Should BPRAC give advice on this? The central approach is not subject to a lot of evaluation. The disseminated approach contains redundancy. Do we want to do materials research in a centralized or disseminated manner? This is a fundamental question. Dr. Wang indicated the need to identify benchmarks before progression to the next stage; any business plan requires knowing who does what, and how the organization is minimizing risk.

Mr. Seery presented the FY04 resource planning process. The WBS has been broken out to Level 3 on this schedule; Level 4 will be integrated into the schedule by the last week of May. OBPR will also create a WBS dictionary defining the products. Product line reviews will begin in September 2004, in anticipation of the next fiscal year. Currently centers are contributing feedback to build the schedule. Dr. Bigelow applauded Ms. Kicza for protecting nontrivial fundamental research. However, he added that OBPR is running up against an old problem (milestones, etc); it is an oxymoron to say there is a metric for fundamental research; one must avoid a way of having metrics that eliminate pure research projects. The cost account intersection was graphically presented. Interface Activities between U and T include an Exploration Systems Review Board, a Deputy Associate Administrator's tag-up and a Requirements Development Team. For Lunar Robotic missions, there is the Lunar Executive Committee, the Lunar Architecture Team and the Lunar Exploration Program Analysis Group. Dr. Lahey asked if the microgravity aspects were focused in each code. Dr. Ross replied that fluid physics research will continue; the question is how it will be organized (perhaps by discipline, as it is now performed). This is to be determined. Dr. Kronenberg commented that the human health and performance area is reflected in Level 3 language; the radiation protection sector should match (and

does not). Dr. Fuller noted that there is a great risk of stovepiping, especially in radiation risk to humans and cautioned OBPR to keep the interaction going. Ms. Kicza agreed the radiation issue as related to human health is such an important issue that it warrants specific attention. Dr. Kronenberg averred that this should be reflected in the WBS; it is currently disconnected from its underpinnings as a health issue. It's an appearance issue. Dr. Ross noted that OBPR does have a board devoted to radiation health.

Mr. Seery summarized the presentation by stating that the center content analysis team performed the analysis of PBS developed by OBPR division directors, performed a gap assessment, and developed the OBPR WBS to Level 3. Dr. Duke asked how the Enterprise is dealing with the current level of uncertainty in architectures and missions. Mr. Seery responded that the WBS would have been put in place regardless of the vision; it will stand the test of time. It has worked well in many different environments. The plan is flexible enough to tolerate political changes. The first three levels should stay the same, regardless. Dr. Duke remarked that Code T is not defined beyond a few high level objectives- there is a lot in Code U that will require some iterative processes between both codes. Dr. Baldwin invited committee members to offer observations for preliminary recommendations. Ms. Kicza summarized for new members the type of advice she needs from the BPRAC; she requested proactive advice on strategy, checks and balances on the OBPR pathway, help on how to transition to the new vision, and help in engaging the broader community on guiding the OBPR. She wanted to be more forward thinking and was concerned about sustaining the vision over the long term. The product line approach is very different for NASA. Dr. Lahey commented that he needed to see more emphasis on the physical sciences. Dr. Musgrave observed that the problem appears to be that the Critical Path Roadmap is trying to catch all elements, but the "Bioastronautics" title of the critical path is throwing off perceptions. Dr. Baldwin recommended the committee provide two types of feedback on the broader issues- critical issues that can be dealt with in-house, and larger problems to forward to the NASA Advisory Committee (NAC).

Proposed Relationships Between NASA Researchers and External Experts

Dr. Howard Ross presented the reprioritized research plan for the transition, and the new relationships between research and external experts. Fear of the research community's being disenfranchised by the President's new vision lies beneath the BPRAC's previous findings on the need for a transition plan for the science community. The new exploration vision is likely to end ongoing research projects, resulting in a negative impact on a substantial portion of the research community and resulting in a loss of skills. It was also recognized that a rapid response was necessary to implement the vision. Traditional NRAs were seen as inadequate to address these needs. Without broad NRAs, the community might become insular. A new acquisition strategy is needed to balance the need to maintain ability and skills to generate new ideas, the need to deliver the flight products expected of OBPR, and the ability to reliably utilize a scarce resource: the ISS. In the latter case, the vision for space exploration defines the emphasis for work performed on the ISS. ISS is a difficult laboratory for PhD students, and it is expensive to maintain "marching armies." Other historical problems are the sporadic nature of NRAs, rescission of grant funding by NASA, complexity of NASA's flight requirements, changing and late-breaking ideas from PIs, and rarely successful maturation from research to flight-ready hardware or techniques. A product line approach should greatly improve this last problem.

The new acquisition strategy is a work in progress. The strategy seeks to assure at least today's aggregate funding level set aside for PI grants through NRAs; maintain traditional NRAs for

noncritical items; provide a directed research approach for time-critical problems; the ability to draw on the pool of previously funded PIs, NASA personnel at centers, and the capabilities of OBPR funded institutes; and the ability to use the ISS predominantly for critical problems in exploration. There is a relatively flat budget for OBPR for the next five years. Dr. Faeth commented that the bulk of OBPR research has traditionally been fundamental- will OBPR be doing less fundamental research in the future? Dr. Ross replied that the short answer is yes, there will be more targeted research and there will be less fundamental research. The fundamental physics flight element is being targeted for termination. Dr. Faeth strongly recommended that the hard work in developing fundamental research should be maintained so that a cadre of researchers will not be lost to the future. Ms. Kicza noted that the free flyer program can maintain the flight-based fundamental physics research program. Dr. Faeth observed that DWGs have been important to this effort, as well as the workshops that brought together researchers in a particular discipline, seems to be slipping away. More time should be devoted to keep this sort of activity alive, otherwise OBPR will lose visibility in the research community. Dr. Merrell commented that he had heard some numbers at the NAC meeting; the difference in the entirety is $1.3B and there is another assumption that Congress will eliminate $338M in earmarks per year. He warned to OBPR not to count on ISS deals being made as a *fait accompli*; the affection of the community cannot be retained with the slim budget. Dr. Ross replied that OBPR is retaining flexibility to respond to the two different scenarios. Dr. Bigelow commented that "what have we acquired from you lately?" will become a watch phrase. Dr. Anderson observed that NASA supports the research infrastructure in the US; eliminating this support will diminish the perceived value of NASA. Dr. Lahey noted that the pendulum has swung both ways since the Apollo program; some NASA programs were outrageous due to outside influences. This new strategy gives NASA the opportunity to get good science and political support. Dr. Kronenberg asked why there was no opportunity for OBPR to have an increased research budget- this is the best time to ask for an increase. Ms. Kicza replied that NASA has carved out of its budget $12B to enable the vision, plus a request for $1B; OBPR has been stabilized, and bioastronautics was increased by 60%; other enterprises have suffered more. Ideally, Code U needs to illustrate what can be delivered within the budget; in the larger scheme, OBPR has accomplished quite a bit. Dr. Wang seconded Dr. Kronenberg's remark; one can choose the conservative approach, but because we are in the strategic point of a new era, one might as well ask. Money drives the technology. Ms. Kicza replied that her approach is to show impacts of not receiving certain monies; she wanted to have everything in place before she determined a budget requirement. She added that she was waiting for inputs from centers and product leads, as well as timelines, before OBPR can make a final budget determination. Dr. Duke stated that he would like to see the organization be more entrepreneurial and go beyond what the Administration has presented to it. Mr. Stephen Day interjected that the general public is not fully enamored of the exploration vision. Congress is also not totally supportive, in both cases because of cost and unknown factors. However, OBPR might use the R&D side to bore in on the budget problem; this may support a mild budget increase. Dr. Borer commented that there is less support for the alternative to the President's vision; in this case one must take advantage of the focus and make the most of the available funding, even if the program must be tailored to the budget and the vision. When we learn about microgravity's effects on humans, we are learning fundamental processes; NASA is a unique laboratory. Ms. Kicza remarked that the Senate has affirmed the authorization for the vision; NASA is stronger with the vision than without it. The Agency has made a budget projection and Level 1 requirements must be put into place before realistic budget figures can be introduced. As a further example of Outreach efforts, OBPR is working on a program called a Day in the Life, highlighting how NASA touches everyday life (improved food safety, e.g.).

Dr. Ross continued with his presentation. If OBPR is currently supporting a PI whose work is not aligned with the vision, it will extend funding thru FY05 with plenty of lead time (there are currently 852 PIs). NRAs would be maintained with improved regular release dates (despite continuing resolution obstacles), focused solicitations would be offered (these may be ground-based or flight). Advantages of this approach include assuring the community's skills are congruent with NASA and community needs, but a disadvantage is that NASA does not spend all of its resources on near-term critical problems. Dr. Faeth suggested separating out NRAs on the basis of long-term, non-vision-related projects from other directed or targeted research efforts. Dr. Lahey commented that the Office of Naval Research (ONR) and the Defense Advanced Research Projects Agency (DARPA) involve their people much more in the direction of research, and suggested soliciting teams, having a program manager select members from a team, and having the manager eliminate non-performers. Dr. Faeth observed that the fundamental research portion of NASA might be better organized like NSF; NASA needs to bring centers into this activity.

Peer-reviewed directed research environments will be used for time-critical research. One advantage of this approach is that it breaks down stovepipes/artificial barriers. The key to the prevention of picking favorites is annual customer-focused, peer-reviewed, publicly available reports. NASA can always bring in consultants when necessary. Dr. Duke commented that potentially this can become a closed group. Dr. Ross replied that the problem is who decides who will be admitted. Dr. Fuller asked what this implies for international interactions- will they become part of the targeted activity? Dr. Ostrach interjected that OBPR would maintain an open conversation with international partners. Ms. Kicza added that she had personally spoken to ISS international partners and found great interest in collaboration. The European Space Agency (ESA) has incorporated the Presidential vision into its presentations to ESA members. Dr. Kronenberg suggested simply broadly advertising the directed-project team. Dr. Ross replied that OBPR is already doing that on a trial basis in the bioastronautics division. Timeframes of different announcement approaches were briefly debated. Dr. Lahey commented that it sounds like a Work Projects Administration (WPA) program, trying to appease disgruntled workers who are losing work. Dr. Borer countered that he likes this approach better than the team approach; it is more disparate in how selections are made to determine a solution to a problem. The real competition would be to choose the people with the right credentials. Dr. Bigelow seconded Dr. Borer's comments, but was still concerned about the centers and their funding stream. Ms. Kicza remarked that an independent peer review is the best way to address this concern. Dr. Bigelow asked how the portfolio would be balanced between noncritical and critical projects. Dr. Ross replied that it hearkens back to concerns about reorienting the skills of those people who are not aligned with the vision. It is not all black and white. Dr. Kronenberg asked if, in terms of the broader research community, there was a way for NASA to put out a request for information in order to get an indication of interest to enlarge the pool of eligible PIs for directed research. Dr. Duke found it odd that Code U is going to an approach like this, while Code T is going to issue a BAA, representing about 75% of the program, to solicit research. Dr. Ross averred that the Code U approach is not that different from the Code T model. Dr. Merrell commented that DARPA is distinguished by timeline (20 years); separation (of critical vs. noncritical concerns) may be the best way for clarity. In the Department of Defense (DOD), the portfolio manager usually asks for a preproposal that contains clear orders from bosses; the portfolio manager will come back and mold the project after the peer review acceptability. The portfolio managers should not make this a banquet for the centers. DOD, DARPA, NSF, etc., have a rationale that is intrinsic to the public; by contrast, NASA has an imagination-fueled

purpose. Dr. Wang observed that if a vision is in place, NASA's position is not any different. Dr. Anderson commented that agencies have a suite of solicitation methods; they also do white papers and compete teams against one another for money. They also pick and choose from teams, and utilize quarterly reports. The program manager has a lot of power to mold the program. Dr. Baldwin recommended NASA maintain an image that it is all encompassing in its research portfolio, and is open to all. On the other hand, there has been a frame shift that requires missions with much tighter schedules and mission timeframes. NASA must have a funding program for the freethinkers, and a separate means for putting teams together to accomplish certain projects. This hybrid infrastructure allows flexibility.

Dr. Ross continued with a brief description on how to selectively use the ISS. Next steps are to ask for and factor in advice from the BPRAC, and proceed with this approach as OBPR develops the POP. Dr. Wang suggested asking a DARPA program manager to give the OBPR/BPRAC a talk. Dr. Ross welcomed individual help from committee members to flesh out the approach, via teleconference and e-mail.

Animal Models Workshop Report

Dr. Charles Sawin presented the results of a workshop in Woods Hole, MA that addressed the relevance of animal model research to the mitigation of human health risks in space. Some key Russian researchers in Russian countermeasures, and the Bion series of satellite flights, were involved. A good animal model (with a cellular component) is required to support space flight. Dr. Sawin invited a dialogue on the results of the workshop, for which written documentation had been provided. Dr. Ron Merrell mentioned that he had gotten to know the Bion project well and agreed there was no way to accomplish human space flight without small animal research. As a result of Bion flights, some important post-flight complications in humans (re: reactions to general anesthesia) have been recognized. He added that animal welfare protocols should be reviewed before such research is put into place. Dr. Fuller averred that the loss of an animal on a Bion flight killed the program through Congressional pressure and animal rights activity. Animal loss has been terminally problematic for these missions. Dr. Merrell noted that the remainder of the research project in question had been invalidated due to the small *n* of the experiment; he didn't believe animal rights issues killed the program. Dr. Sawin stressed the importance of utilizing appropriate models for appropriate questions. The availability of a centrifuge for cellular studies is being considered in Free Flyer missions for providing variable gravity conditions. Dr. Borer endorsed cellular research in space as an extraordinary opportunity for human cellular research. Dr. Kronenberg expressed concern that none of the science presentations concerned radiation research. This is a troublesome disconnect. A meeting attendee noted that there was no dispute on radiation's importance; it had been decided to treat radiation as a separate subject. Dr. Wang remarked that there is a growing negative mentality about animal models that must be considered, and suggested a good alternative may be to maintain a cell bank (there is information on fixed and frozen cell samples, from past flights, in the Life Sciences Data Archive).

Bioastronautics Critical Pathway Roadmap (CPR)

Dr. Guy Fogleman, director of the Bioastronautics research division, presented aspects of the draft Bioastronautics Critical Pathway Roadmap (CPR). The Institute of Medicine (IOM), National Academy of Sciences (NAS), and the National Academy of Engineering (NAE) are in the process of reviewing the draft document. The history of the CPR was reviewed. The document has been revised to include an expanded set of reference missions (to accommodate the new vision), greater

representation of NASA Advanced Human Support Technology and NASA Space Medicine Programs, and improved statements of risk. Characteristics of CPR reference missions were briefly reviewed: 12 months on ISS, 30 days on the Moon, 18 months on Mars. Dr. Faeth remarked that a range of oxygen concentrations should be indicated in a report of this type, as well as atmospheric pressures. The question of variability of atmospheres (fluctuating O levels, $C0_2$) is an active issue with the operational personnel. Dr. Faeth cautioned that high $C0_2$ concentrations cause fire suppression mists to become electrically conductive; such problems indicate that the program will need a wider understanding of a range of atmospheres. In response to a question, Dr. Fogleman replied that the driver for a nonstandard atmosphere was the extravehicular activity (EVA) suit. An attendee commented that there is a fair amount of accepted variability in atmospheres; if crews are going to Mars and not doing science, there is no reason for a nonstandard atmosphere. **Drs. Faeth and Fuller took an action to address the atmosphere issue.**

CPR disciplines and cross cutting areas are human health and countermeasures, autonomous medical care, behavioral health and performance, trauma, real-time medical diagnosis, human habitability technologies, and research supporting the development of lower mass/lower volume, more efficient and reliable exploration systems. CPR integration addresses the reduction of risks; cross cutting areas lend themselves to a "projectized" approach. Risk identification, assessment and management issues have been derived from workshops and academy and advisory committee reports. Types of risks have been classified as 35 human health or medical risks, and 15 system performance- and efficiency-related risks. There is overlap across the different types of risk. Bioastronautics risks (human) are distinguished by color code- red is unacceptable with no mitigation strategy validated in space or on Earth; yellow is high risk of serious consequences with no mitigation strategy; green is consequences are known or suspected, but mitigation strategies exist. The codes are somewhat different for system performance risks. A sample risk data sheet was presented. The 35 human health risks were rated by color. The chart has been broadcast on the Internet for solicitation of comments; thus far about 90 responses have been received. International participation has not yet been solicited on this item. The responsibility for mitigating the human risks lies in Code U. The responsibility for developing multiple scenarios lies with Code U as well. Dr. Duke noted that other codes may be able to mitigate some risks through technology development. A Space Radiation Health Notional Schedule was presented and levels of accepted risk were detailed. Dr. Baldwin commented the CPR seemed to contain translational than basic research; however, much applied research is necessary before the space program could be fully realized. Dr. Fogleman replied that in general, there are categories of countermeasures such as artificial gravity (AG), pharmaceutical intervention, nutrition, exercise, etc. OBPR envisions various projects under these categories in order to derive a set of protocols and prototypes. This would require cross cutting teams and technologies at various CRLs. The expectation is that the research portfolio would be constructed by NASA personnel, with the help of outside expertise. For bone health, there are several countermeasures already in place. OBPR intends to request (of potential proposers) how a proposal will move up through the various readiness levels. There is also an effort under way on AG, including international participation. Several models of solicitation are under consideration.

Questions abound on such physiological issues as how much bone or muscle loss is acceptable for a given flight duration. A five-month effort initiated by the Chief Health and Medical Officer is now in progress to document currently accepted risk levels for the 50 identified risks- a first draft is expected by June. Dr. Lahey commented that many issues are related to duration of the mission. There are no

data on the effects of partial bone loss. Russian input will be taken into consideration on the vetting of acceptable risk levels. Some risks are going to remain nebulous.

NASA is just beginning to utilize its access to newer modeling techniques and high-speed computers to analyze risk for the Mars missions. There will be an interaction of several techniques. Individual variance in risk vulnerabilities can be partially addressed by modeling; long-duration missions will demonstrate these differences most dramatically. In response to a question, Dr. Fogleman replied that three possible goals of defining risk levels were to prioritize countermeasure research, to inform the astronauts, and to inform the public. The primary goal is to prioritize the research. Dr. Borer suggested that the primary goal for genetic profiling is to prevent harm; i.e., to profile the astronauts to decide whom to send where. Dr. Fogleman briefly described results of a workshop held on risk assessment, delineating the minimum number of subjects needed on orbit to address risk assessment adequately. Dr. Fogleman distributed a summary of the results. The answer is that *n* is basically 200 +/- 30. There were no *a priori* study designs underlying the compilation of the results. Dr. Borer commented that the way the ISS crew is deployed could be significantly affected by the study design. Dr. Kronenberg asked whether this was a realistic number, and was told the historical participation rates are congruent with projected assumptions.

NSBRI Presentation

Dr. Jeffrey Sutton provided an update on the activities of the National Space Biomedical Research Institute (NSBRI) (www.nsbri.org) and reported that the institute is thriving. Its charter is countermeasure research and development and is focused on deliverables. The institute has just produced some of these deliverables. NSBRI was established in 1997 through a Cooperative Agreement, following a competitive selection, involving a unique partnership between the academic biomedical community and NASA. It is governed by a consortium of leading academic institutions, with 12 consortium members and has 100 research projects at more than 70 institutions in 23 states. NSBRI maintains a strong and collegial partnership with NASA through working (coordination) groups and individual liaisons. Dr. Sutton reviewed the NSBRI organizational structure, described as a corporate model in a nonprofit organization. There is a subset of NSBRI members (liaisons) who are team leaders: these individuals must be recognized scientists and active investigators, and must have recognized scientific leadership skills. Other liaison positions are being sought to bridge disciplines. Research areas were briefly presented, and the integrated team approach to solving enabling questions on the CPR was graphically represented. The roles of the institute for OBPR are to perform translational research, recruit the best available investigators, and to fill critical gaps in areas such as behavioral health. The institute also helps to integrate research efforts through the team leader roles, cross-team leadership, targeted solicitations, and directing research toward operations. The merit scores for the last joint NRA were presented- the average team leader merit score was 88. Key factors to research success have been coordination of countermeasure development, and functional assessment and transfer of deliverables. The institute supports the national goal to establish a human presence on the Moon and beyond, and provides an acclaimed education and outreach program. A phase I graduate program request for proposals (RFP) is in the queue, as well as summer studentships, and ongoing continuing medical education (CME) for flight surgeons. There is increasing NSBRI participation in NASA laboratories. The institute is also working on establishing a bioastronautics facility, but does realize that this may be the wrong time. Selected research achievements are a demonstration of significant effects of a single-dose IV zoledronate on hip bone mineral density in spinal injury patients, at one year post-injury. This may have a significant mitigating effect on flight countermeasure

selection (due to difficulties of oral administration, such as esophageal injury, of bisphosphonates in microgravity). Another result is development of a portable confocal acoustic imaging device to assess bone mineral density and strength in real-time in the space environment. An Earth application is to monitor osteoporotic disease. Advances in noninvasive diagnostic and therapeutic platforms based on high-intensity focused ultrasound (HIFU) to detect change (as in a bleeding vessel) and to use the same device to coagulate the bleed, were presented. Further achievements were noted: the elucidation of the activity of the atrogin-1 gene, a muscle-specific protein; differences between men and women in social isolation, self-treatment of psycho-social problems, and near-infrared spectroscopy (NIRS) optical tomography for measuring blood and tissue chemistry (such as pH of muscle in unstable patients). Earth applications include noninvasive detection of perfusion problems in diabetes. Molecular responses to different wavelengths, based on research derived from mouse rod opsins that detect blue light, and their relation to circadian rhythm, can entrain melatonin and cortisol, depending on the blue shift, and affect the sleep cycle. A miniature matrix-assisted laser desorption-ionization/time-of-flight (MALDI-TOF) device to evaluate in-flight samples has been developed; there is no current need such a device for space flight on ISS, but it has applications for Homeland Security. In conclusion, the team leadership was felt to be the key to research success, with the institute providing a clear added value to the program. The power of the institute has not been fully realized. The level of funding is $30M, with $29M for nondirected research, and $1M for a space medicine line. Ms. Linda Billings asked about guidelines and requirements for communications imposed on researchers, and how outreach was conducted. The response was that at every level, there is a representative for education and outreach. About $2M is expended per annum on this effort. Press releases are issued for major results.

International Space Station (ISS) Exploration Research Planning Status

Mr. Peter Ahlf presented an update on the challenges on ISS, including matching capacity with requirements, such as deployment of facilities and conduct of research during assembly, number of human research subjects, post-shuttle retirement, downmass issues, launching live specimens and thermal conditioned transport. He identified all the facilities relevant to the new vision and found that everything that was in development for ISS was relevant to Exploration. The upmass summary was presented by category: outfitting, re-supply (specimens, samples), conditioned stowage outfitting, and human support systems outfitting. Additional work is needed to match requirements against capability, assuming a maximum flight rate of the Shuttle fleet, as well as Russian and Japanese vehicles. There is some consideration of expendable launch vehicles (ELVs) primarily in the post-Shuttle phase. 2006 is a big problem; the outfitting requirements may have to shift to the right, or there may be a delay in a milestone for a particular product. Traffic models have been developed for rodent research and other categories. There is some plant research included in the human support area; however some projects considered for cancellation do include some plant research holding racks. Free flyers may be able to take up some of these cancelled items. Human subjects needed under different assumptions were presented; the program would achieve 70 subjects by 2016 at 2 increments per year. Use of Soyuz vehicles would engender some unique resupply needs. Post-2010 challenges include power for payloads, downmass, late and early access (important for biological research), and international standard payload rack accommodations. NASA is engaged in discussion with international partners to help with the downmass situation, power, and late and early access; it is also looking at modifications of vehicle design, and to US industry for new capabilities. A request for information will be released in the Fall of 2004. Options are being analyzed to reduce ISS research requirements while preserving the ability to meet research goals for the ISS. Dr. Baldwin asked if there were anything percolating to eliminate assembly modules to alleviate problems. Mr. Ahlf responded that they are looking carefully

at every element and asking questions about every major element. Various trades relevant to node 3 were discussed. Dr. Fuller asked about the status of the Centrifuge Accommodation Module (CAM) and the centrifuge. The response was that there is a position paper that will be reviewed in June, with external vetting, explaining why animal research is important to human space flight. CAM and centrifuge delivery will take up an entire flight. Primary competing interests in mass are re-supply and delivery of large assembly pieces. Orbiters in and out of servicing, and constraints on Shuttle flights are factors influencing ISS utilization as well. Retirement of the Shuttle is necessary to free up the money necessary for Exploration; the new vision drove the decision to retire the Shuttle.

Discussion/Issues for comment and recommendation

Dr. Baldwin requested comments and made writing assignments:

- Atmospheric conditions- Drs. Faeth and Fuller
- WSB product development- Drs. Borer, Anderson, and Rothenberg
- NSBRI new vision deliverables- Dr. Daley
- Buildout; ultimate deliverables needed for human flight to Mars
- Delegations to the subcommittee of BPRAC – one is a festering topic in the "Old Guard" (how to form the subcommittee infrastructure)- should we go to task force infrastructures to deliver particular products? Rules need to be defined on how to do this.
- There is no model on how to organize the directed research teams. Dr. Rothenberg felt it needed just a little fine-tuning and positive reinforcement.

Dr. Wang commented that the directed research idea is still in an embryonic state; it needs some more fine-tuning and pilot missions. Dr. Lahey reiterated concern with the diminution of focus in physical research. Dr. Faeth felt it was necessary to comment that in this new direction, the physical sciences should not be left out. Dr. Lahey agreed to write a finding on the retention of a robust physical science research program.

Dr. Faeth was distressed about the way subcommittee structure is being handled. *Ad hoc* task forces will not work for monitoring fundamental research in OBPR- it needs a real focus. He was also concerned about the DWGs dying off because they have no one to report to, and saw these groups as vital to fundamental research. Dr. Fuller asked: how do we respond to the strategic planning in time for the next fiscal year- how will we accomplish everything? Ms. Kicza should bring the committee up to speed on her vision for strategic planning. Dr. Borer added that task forces were meant to be a temporary solution until OBPR was more clearly focused. Dr. Rothenberg commented that given the state of flux and the committee's competencies, BPRAC should agree to go back to standing committees. There is insufficient time for the BPRAC to identify all the issues, and Ms. Kicza must be engaged to move forward. Dr. Bigelow suggested asking Ms. Kicza for a briefing on strategic planning over the next year, and also to address fundamental research's place in the WSB. Dr. Anderson commented that NASA is trying to manage change and the tendency is to overreact- the BPRAC's role is to caution and to provide an external objective view.

It was felt that the task force approach is insufficient and that two standing committees should be re-formed (life sciences and physical sciences). Dr. Faeth agreed on the need to protect fundamental research and felt some of these committee meetings could be performed by teleconference. Dr. Duke averred that this is an urgent matter because decisions are in the process of being made. Ms. Billings

agreed that this approach will support Ms. Kicza's call for sustainability. Dr. Duke felt that the big problem faced is in the tension between retaining the old program and the new vision. We seem to be trying to inject inertia into this process. He added that it's not clear that maintaining the NRA structure is equivalent to maintaining basic research. A report on the division between directed research and basis research should be requested before the FY06 implementation. Dr. Faeth suggested incorporating the subcommittee structure remark into this recommendation.

ISS Utilization Update

Dr. Donald Thomas presented an update on recent ISS activities and related that until RTF, upmass capability to the station will be severely limited. Progress and Soyuz are the only vehicles available for upmass transport; only 44 kg have been transported to orbit since the accident. Limitations due to cancellations of some Russian flights have hindered operations. Some in the program feel that the Russians are trying to make a point. It is primarily a monetary matter, and additionally the Iran Nonproliferation Act prevents some flights. Downmass is not much better (about a pound up and a pound down). Life science experiments have been delayed and a renal stone experiment cancelled. The FOOT experiment cannot be performed. Expeditions 7-9 can be continued due to lighter mass requirements. Interactions and journals can continue. Advanced ultrasound (US) can continue. The average crew time per week will vary; early on it was 14-15 hours per week and now hovers around 7-10 hours. EVA takes away much crew time from science. The Expedition 8 science summary was presented. US HRF was used to develop telemedicine capacity, operations with CBOSS (fluid dynamics investigation) were performed, and seven science demonstrations were completed. Strong international cooperation was seen. Potential breakthrough technologies were discussed. Delta mission science was briefly summarized; its high point was that it achieved 30–40 science hours in 8 days. Expedition 9 science status was presented. Dr. Baldwin commented that research into markers of muscle atrophy (from animal models) are currently being translated, and emphasized the importance of correlating these data with potential findings in humans.

Looking ahead to Expedition 9, last minute crew changes have been challenging. The program has been re-prioritized to focus on vision-critical science experiments. Dr. Lahey commented that it looks like the number of the biological experiments is related to the critical path; but it looks like the physical experiments are not; he didn't see the physical experiments as contributing to the pathway to Mars. Dr. Baldwin commented that some of these experiments reflect past planning; there is now the opportunity to reinvigorate the physical science research for congruency with the Mars vision. Dr. Anderson observed that the biological side is very explicit, and the physical side is more diffuse and subtle- mapping it will be a difficult job. Ms. Kicza noted that the BPRAC can help OBPR roadmap the physical science requirements. Dr. Lahey remarked that no one knows how to build phase change systems for life support on space craft- this needs to be addressed. Ms. Kicza recognized the need for proof of concept experiments; OBPR needs time to map out the necessary product lines. Perhaps DWGs should remain in their areas, with an overarching philosophy for human support in space. Dr. Faeth suggested starting with the DWGs in the physical sciences, with concomitant committees on physical sciences and life sciences. Ms. Kicza agreed it would be useful to have another teleconference task force on this subject.

Dr. Thomas returned to the briefing. Recent issues included getting the Expedition 8 crew back to the US; it was difficult because Russia wanted the crew (to remain in Russia for a longer period) for some political reasons, but there may have been some medical operations issues. Expedition 10 is proposed

to have a one-year duration, while NASA would prefer 4-6 month increments. Greg Olsen will be the next "tourist" on ISS. The prioritization process is being re-vectored to address the new Exploration focus. There is zero allocation for the Progress vehicle for science experiments. ISS research continues despite limitations, with priorities given to experiments that support the President's vision, and with continued international cooperation. Dr. Baldwin commented that a one-year Expedition 10 is a kiss of death for the President's vision from both the biological and physical science perspectives. Changeover of experiments is critical and would be adversely impacted by a long-duration expedition. Dr. Faeth strongly recommended bringing the one-year increment issue to the NAC, and to make it a finding stemming from the current BPRAC meeting. The Russians have a crew of 2 for one-year durations and they say they will go without the US. Dr. Wang commented that one cannot do any statistical analysis without an n=3 in one year. The means to collect blood on orbit do not exist right now. Sample storage is a critical issue. Dr. Thomas said the –80°C refrigerator is a priority for the next Shuttle flight. Dr. Duke asked: why not develop an expendable carrier that can be launched on a Delta II? The European Space Agency (ESA) is looking at something similar. It is both a funding and development problem. Passive systems that don't vent are being considered, as well as study-return capsules and doing analysis on orbit. There is increasing robustness of baseline data collection in Russia. Dr. Duke observed that Stardust and Genesis are alternatives for returning samples. There is also a Japanese capsule that is similar to those reentry systems.

2008 Lunar Reconnaissance Orbiter Status

Dr. Terri Lomax presented plans for the 2008 Lunar Reconnaissance Orbiter (LRO) mission. In response to the President's vision to initiate a series of robotic missions to the Moon, this mission will launch no later than 2008. Code S has developed successful missions to Mars, and they will be managing these missions. An announcement of opportunity (AO) was rapidly put together to address this. An extended human expedition is to occur as early as 2015 (but no later than 2020). The goal of these missions is to use the Moon as a testbed for Mars.

An AO will be released in early June for the LRO. This is viewed as a measurement mission, and will carry a variety of instruments in a year-long polar orbit to investigate the source of hydrogen that has been detected at the lunar poles. Level 0 requirements for the vision inform the plan for the mission. The charter of the ORDT (Objectives and Requirements Definition Team) was to provide NASA with a prioritized set of measurements that can be attained with a resource- and schedule-constrained LRO to be launched before the end of the 2008 calendar year. Phase A-D schedules were presented on a timeline. An 100 kg experimental payload is planned, with 20 watts of power available for experiments. Dr. Lahey commented that the mission needs a lot more power. It was recognized that the mission is cost-constrained ($300M). Dr. Lahey noted that NASA can't afford to develop nuclear power for the mission without a nuclear program. Dr. Lomax replied that there are three separate nuclear programs. Dr. Duke commented that we don't have the fundamental science necessary for the Prometheus program to build what it needs.

Mission planning includes requirements for measurements of radiation, geodesy, volatiles, and characterization of landing sites. ORDT preliminary findings yielded four primary themes: characterization of lunar radiation environment, biological impacts, and potential mitigation; establishment of a high-resolution geodesic grid for Moon (3-D); polar region resources assessment; and high spatial resolution global resource assessment. Lower priority was placed on partial duplication of anticipated lunar missions. Suggested measurement set priorities were presented. The

"radiation sentinels" rationale includes the need to expand the limited current knowledge on the biological effects of space radiation, and informs development of operational radiation sentinels. A rationale for genetics-intensive payload was presented. Dr. Wang recommended the use of *Caenorhabditis elegans* and yeast as experimental organisms, or human-gene-altered yeast; RNA interference techniques can be used with *C. elegans.* A LunaGene Long Duration option was presented, and strawman mission requirements enumerated: <10 kg payload with an In Situ Genomics on Satellites (ISGEN) preliminary technology concept, including polymerase chain reaction (PCR) and microarray experiments. More information on payload can be found at www.centauri.larc.nasa.gov/LRO. The research community will be engaged via workshops to obtain information on payloads for the lunar testbed. A Lunar Expedition Program Advisory Group (LEPAG) (similar to MEPAG for Mars), and internal working group, and a measurements requirement group have been established. Mr. Day commented that it the public relations aspect of the mission is important to satisfy a frustrated public; NASA must link applications to Earth and the public must buy into the program. Dr. Lomax felt that the biological slant of the first mission may engage the public. Dr. Wang observed that the mission represents a chance to advance technology integration for the support of the biological experiments; radiation generates oxidative damage and we need new technology to measure damage to cellular lipid bilayers, e.g. It is a good opportunity to have cross-talk between disciplines, and a chance to address individual genetic differences by integrating technology. AFRI (Bill Blakely) has developed some instrumentation helpful to the mission. Dr. Duke suggested that Code U consider finding extra money to help support the mission, as it will be high visibility. Yeast deletion strains and *C. elegans* have been flown on ISS before. Dr. Anderson asked if there were evidence to link microgravity and radiation? Dr. Kronenberg stated that this was the experiment itself. The issue of microgravity is more critical in multicellular organisms where gravity may influence the 3-D configuration in growth and development. The mission must be careful not to promise too much of an outcome.

Crew Exploration Vehicle (CEV) Presentation

Mr. Garry Lyles of Code T discussed the development of the Crew Exploration Vehicle (CEV), dubbed the Constellation Program. The long development time is driven by budget. Doubling the money for the mission would probably reduce development time from 10 years to 6 years. There is not yet a requirement for the CEV to go to ISS. About 1000 responses have been received from the RFI. A Broad Agency Announcement (BAA) will be put in place for refinement of concept and development on June 14, to be awarded in September 2004; that will constitute a first look at requirements for CEV. There is some work going on considering the capacity for gravity-equivalent delivery, and perhaps a go/no-go analysis. Level 1 requirements inform the research. A preliminary gap analysis has been performed for technology development to help identify big-impact elements of the total architecture. There will be a human and robotic technology BAA to address these gaps in late 2004. Dr. Lahey expressed concern with basic research for power and propulsion.

Codes U and M are contributing to the technology development of the CEV. Spiral development was defined for the benefit of the committee. In DOD, Pete Aldrich has introduced a solution for shortening technology development cycles (don't buy everything in one chunk); this is useful when one cannot initially define all the requirements for an architecture; it is a form of evolutionary acquisition. Key considerations include early delivery of initial capability. Development Spiral 1 has been defined as Manned Space Vehicle, Spiral 2 will be lunar surface, etc. Systems integration must be performed across spirals. Habitats must be developed for long-duration missions to Mars- this requirement must

be integrated into the technology development from the start. The CEV program is in the process of formulating the acquisition strategy based on the RFIs and BAAs. NASA has had to shut down two major programs and transfer pieces into the Exploration effort (such as hypersonic propulsion, which has been moved to aeronautics). Sensor technology and avionics will be tested on the Dark Project. Orbital Express (in concert with DARPA; Defense Advanced Research Projects Agency) represents the next step in autonomous docking with a satellite. There is an Exploration Communication Working Group- any new development will probably be done within Code T. Hoping to start with COTS.

The Constellation Program acquisition strategy overview was presented in baseline terms. Multiple demonstration flights are planned by 2008, with an unmanned CEV flight by 2011. Crew capacity is not yet known (although early indications point to 4), or whether the vehicle will go beyond low-Earth orbit (LEO). Functionality is still open. Psychosocial research results will help determine final crew size. There was concern expressed about nebulous concept of the CEV. The response was that Constellation includes the CEV, as well as other space transportation systems that will include functionalities not included in the CEV. It is also supporting in-space systems, such as propellant space depots (used as filling stations in space), and supporting surface systems (habitats, rovers, power, special tools). Constellation coordinates with Operations through Code M and JPL. It doesn't have an explicit interface with Code U. Ms. Kicza noted that most touch points occur in the human/robotics technology and through Codes Z and M for human health requirements. The megawatt power capability for Mars is probably being addressed in the Prometheus program. The highest risk areas are sustainability and affordability. Dr. Faeth requested more frequent updates (more than once per year).

The BPRAC turned its attention to developing findings and recommendations. After discussion and formulation, the meeting was adjourned.

Appendix A

Findings and Recommendations

Research Acquisitions (Kronenberg- Anderson)

Findings:

BPRAC applauds the commitment of OBPR to protect the current funding level for investigator-initiated grants solicited through the NRAs for the next five-year period. BPRAC endorses the two acquisition strategies outlined for both basic research studies that are not time-critical and directed projects that are time-critical. It is recognized that each type of NRA (basic research vs. directed projects) may be served best by approaches tailored to the category of research sought. Effective practices for proposals that are not time-critical include the use of peer review, community-initiated workshops and Discipline Working Groups to assist in drafting announcements, and regular release dates. For time-critical proposals, the use of competing teams, pre-proposals, and milestone-driven schedules may be merited.

BPRAC endorses the regular issuance of NRAs, preferably on a fixed annual timeline, and their timely assessment and recommendation to address needs that are not time-critical. (Editorial Comment by Amy***The management structure of OBPR is a separate topic, and we did not consider this adequately during our discussions. It seems prudent to omit any discussion of OBPR's management structure from this particular issue, which relates to the approaches that Code U will take to securing its research objectives).

BPRAC recognizes and endorses the commitment of OBPR leadership to maintain a substantial investment in basic research while it integrates new programmatic requirements that may be served better through directed research opportunities. The BPRAC advises the OBPR to be cognizant of the greater context of its research portfolio, in particular, its relation to the research programs in other federal agencies. Opportunities may exist to build partnerships with these other programs to leverage resources. The OBPR should be world-class in those research areas that are essential to its mission. In particular, specific aspects of research in the biological and physical sciences are both expected to be essential in the newly defined mission.

Although OBPR management has indicated commitments to maintaining both basic research and the NRA process, it was not clear to the BPRAC whether those commitments translate into maintenance of basic research at the current funding levels (percentages), or whether components of the NRA solicitations would be transitioned to Code U project-directed research.

Recommendations:

1. BPRAC recommends that the current funding commitments to basic research be maintained through the NRA process, with funding for directed research coming from additional resources obtained by reprogramming and other sources.

OBPR is requested to report to BPRAC on the implementation plan for the FY06 budget at the next meeting with regard to the anticipated balance between NRA and mission-directed research. Individual NRAs should be limited to either basic or applied research.

Project Teams for Planning, Review, and Implementation of Research (Borer)

Finding:

Concern exists regarding the adequacy of relevant biological knowledge to optimize the design of the intravehicular gas and pressure environment for human space flight, despite some fundamental research that underlay decisions 20 years ago. This situation illustrates the potential to move prematurely to application with inadequate enabling research, under political and budgetary pressures to provide short-term evidence of practical programmatic achievements. BPRAC believes the risk is relatively high that repetition of a pattern of premature application will occur at the expense of appropriately comprehensive research, particularly if management is based solely on an engineering model of predictable availability of enabling deliverables. Therefore, BPRAC is favorably impressed with the general plan of OBPR to create broad-based project teams. These include NASA and non-NASA personnel to plan and review the adequacy of basic research related to pre-specified critical issues before design decisions that may be difficult to modify are put into implementation mode.

Recommendations:

2. BPRAC strongly supports and suggests enactment of OBPR's plan to create project teams representing wide-ranging interdisciplinary expertise to (a) define critical questions for biomedical research and for facilities/environment designs for human space exploration, (b) design research plans to resolve these questions, (c) monitor progress of resulting research so that mid-course corrections can be made in study designs, resource applications, etc., and (d) determine the extent to which the research, when completed, is adequate to support facilities/environmental architectures necessary to support long term space mission scenarios.

To meet time constraints defined by executive mandates, project teams should be selected based on the quality of short summary proposals in response to Requests For Information to permit assessment of the quality of applicants, with final study designs and protocols defined by the project team after its formation. This model envisions inclusion of multiple applicants on a team, and the involvement of NASA and non-NASA personnel, the latter including scientists already funded as NASA PIs as well as non-funded experts.

BPRAC requests a report on the progress of initiatives (1) and (2) at its next meeting.

Space Program Habitat and Spacesuit Atmosphere (Faeth)

Findings:

A variety of habitat and spacesuit atmospheres have been used over the history of manned space flight and on Earth. At the present time, the normal atmosphere of the Space Shuttle, Russian spacecraft and the ISS involves a nominal 21% O2, diluted mainly by N2, with a total pressure of 101.4 kPa (14.7

psi). Current exceptions to this involve relatively brief periods (one day or less) on the Space Shuttle during preparation for EVA, where oxygen concentrations are increased to 28-31% with the total pressure reduced to 70.3 kPa (10.2 psi) and within space suits where the atmosphere contains 100% oxygen. Other atmospheres, generally involving enriched concentrations of oxygen, however, are under consideration for future space habitat atmospheres because they offer system advantages in terms of reduced weight, etc. It is known, however, that atmospheres having enhanced oxygen concentrations definitely increase fire hazards, e.g., the Apollo fire involved a spacecraft atmosphere having an oxygen concentration of 100%. Reduced total pressures of the habitat atmosphere are generally used to mitigate the fire hazard, however, the technology base available to evaluate the effectiveness of reducing the fire hazard using such approaches is very limited at normal gravity conditions and even more limited at the low gravity conditions of spacecraft. Finally, finding acceptable habitat atmospheres for manned spacecraft missions in the future, considering both the response of living organisms and the fire safety implications of the atmosphere, is obviously a very important issue that will affect manned space operations that will only increase in activity in the future.

Recommendation:

3. Properly resolving the issue of space program habitat atmospheres will require an energetic program to determine acceptable atmospheres from the standpoint of both the health and normal behavior of living organisms as well as effective fire safety. As a result, these conditions can affect research of interest to BPRAC. In view of the importance of this issue, BPRAC requests a report of NASA's activities in this area at its next meeting.

Status Report From the National Space Biomedical Research Institute (Daley)

Findings:

Dr. Jeffrey Sutton, Director of NSBRI, briefed the Committee on the status of this institute. A consortium of 12 member universities governs the institute. The NSBRI, in its seventh year of operation, has recently modified its management organizational structure. The research team structure is designed to accomplish research at technology readiness levels (TRLs) 2 through 7 and countermeasure readiness levels (CRLs) from 4-8. Dr. Sutton provided several examples of successful research efforts that are ready for flight validation. Successes included reduction in bone loss in spinal injury patients through a one-time injection of zoledronate; also productivity improvements (in sleep-shift workers) were noted with exposure to blue light. Both Code U and the NSBRI are to be commended for providing the stable funding stream and the program stability, respectively, that has allowed this institute to mature and succeed in such a short time.

Recommendation:

4. Using the NSBRI presentation as a model, OBPR is requested to present an update of each Code U-supported institute, one per BPRAC meeting. The presentation should include funding levels, leveraged research funding, examples of successful research and education and outreach efforts. A concise report prior to the meeting would be helpful.

One-Year Increment (to be brought to the NAC) (Baldwin)

Finding:

BPRAC was briefed on the status of ISS research and noted that crew turnover of ISS is being proposed by the Russians to be transitioned to one-year increments, beginning with Expedition 10. BPRAC views this strategy as deleterious to completing the ongoing and future research needed to fulfill the President's vision for human exploration of space. Such a strategy would severely reduce (1) the number of human subjects available to generate the database for understanding human physiology necessary for long-term space exploration, and (2) the number of biological and physical sciences experiments available to support human health and function for space travel.

Recommendation:

5. BPRAC recommends that any strategy of one-year increments on ISS for astronaut turnover be rejected and recommends implementation of a plan for 4-month turnovers. Further, BPRAC recommends that NASA implement its original plan for 6 crew members per increment in order to meet its scientific objectives. (current status is 3-6 months; future status, one year)

The Apparent Imbalance of Biological and Physical Research in the OBPR Research Roadmap (Lahey)

Findings:

A previous National Academy study [Viskanta; NRC, 2000] identified several "show stoppers" associated with the proposed human exploration of Mars. These critical capabilities were concerned with enabling technologies in both the biological and physical sciences. The proposed OBPR research roadmap addresses many of the key biological issues identified but does not adequately address the issues that will require advances in physical research It is significant that the specific research recommended by the NRC has also been endorsed by several subsequent NASA Workshops and Scientific Working Groups (SWGs), and thus these research initiatives have been thoroughly peer-reviewed and have broad support by the scientific community.

Recommendation:

6. To support NASA's new programmatic needs, the proposed OBPR research roadmap needs to be expanded to ensure that the physical science research that has been identified as enabling technology is included in the research plan and it is requested that this revised roadmap be presented at the next meeting. It should be stressed that the current OBPR research roadmap is well focused on technologies associated with the human body. The research needs of the physical sciences are more diffuse but no less important.

BPRAC Subcommittee Structure (Baldwin)

Finding:

During its deliberations, BPRAC noted that final decisions have not been presented with regard to the infrastructure that OBPR will use to define the subcommittees and investigator working groups that will be used to support BPRAC in fulfilling its mission as a pro-active advisory committee even though there has been considerable discussion on this topic.

Recommendation:

7. BPRAC recommends that a subcommittee be formed to interact with the associate administrator, Mary Kicza, to complete this process so that the new sub-committee infrastructure can be presented and implemented at the next BPRAC meeting.

Participation of Code U in the Lunar and Mars Robotic Missions

Finding:

BPRAC heard Dr. Terri Lomax report on this activity and was impressed with the highlighted importance of radiological health. The BPRAC was pleased with the participation of Codes T, U and S.

Recommendation:

8. BPRAC requests continued briefings on the interplay of Codes S, T, and U in formulating these missions and on the progress of mission development.

Code T/Code U Relationships: Identifying Needs and Code U) Opportunities (Duke)

Finding:

It is not clear from presentations received by BPRAC that a complete set of research/technology tasks appropriate for OBPR research and development programs have been identified. BPRAC is particularly concerned that the general area of materials research for which OBPR represents a significant research community capability is not adequately represented, but there may be others as well. It is not clear whether a mechanism now exists for OBPR to evaluate all aspects of the Exploration Systems program that may require basic research in areas such as materials, fluid flow, and combustion. Furthermore, the development of the OBPR "product lines" may overly constrain OBPR personnel in their identification of promising research areas appropriate for OBPR, but not included among the core OBPR interests. If OBPR does

not adequately evaluate exploration research needs and include them in their program, the Exploration Systems Office may need to perform scientific research to address uncertainties when they arise in their technology development programs. It is also unclear whether appropriate boundaries are being established for handoffs from OBPR to the Exploration Systems Office for which OBPR has accepted responsibility.

Recommendation:

9. OBPR is encouraged to implement a mechanism (e.g. in-house evaluation, research community workshops) to understand the full range of science underpinnings needed to support Exploration Systems Office technology developments. This is clearly more important in physical science than in the life science areas.

OBPR and the Exploration Systems Office should be encouraged to define the mechanisms by which the handoff between organizations will be managed. This may be different for various types of technologies (e.g. human-system vs. non-human-related technologies).

Facility Class Hardware to Support Research on ISS (Musgrave)

Finding:

Although specifics were not given, presentations stated that 9 pieces of facility-class flight hardware and 2 express racks were targeted for cancellation in order to align OBPR with the goals of the exploration initiative. Similarly, the status of the large diameter centrifuge rotor was again in question. The centrifuge and its full complement of habitat inserts are crucial for conducting research in basic biology on ISS—basic research that will support and sustain the exploration agenda. Furthermore, basic research in the physical sciences can feed the technological underpinnings needed for achieving milestones on the Critical Path Roadmap. It is unclear if the complement of facilities being considered for ISS will be able to support the scope of basic research that is needed in the microgravity environment in order to sustain the exploration directive.

Recommendation:

10. Because no other platform for research in microgravity will be available for some time, it is important to ensure that basic research competencies on ISS will be available. The large diameter centrifuge and its habitats are key to providing fractional-g models for lunar and planetary surface missions. OBPR should not react hastily to terminate ISS hardware while the "product line" approach to meeting the exploration agenda is still in development and the key role to be played by basic research has not yet been articulated with specifics. It is crucial to retain a science perspective for defining the role of ISS, and the committee recommends that guidance be sought from the scientific community before canceling development of facility class hardware. BPRAC represents a broad cross-section of the scientific community and could provide OBPR guidance in this matter.

Appendix B

BIOLOGICAL AND PHYSICAL RESEARCH ADVISORY COMMITTEE MEETING
NASA Headquarters
Washington, DC
May 20-21, 2004
MIC 6

Thursday, May 20

9:00 A.M.	Welcome/Chair's Review of Agenda/Logistics	Dr. Baldwin
9:10 A.M.	Ethics Presentation	Ms Gilchrist
10:00 A.M.	Review of BPRAC Recommendations	Dr. Ostrach
10:30 A.M.	OBPR Program Overview	Ms Kicza
11:30 A.M.	OBPR Exploration Product Lines	Mr. Seery
12:30 P.M.	Lunch - Animal Models Workshop Report	Dr. Sawin
1:30 P.M	Design Path for Rodent Habitat	Dr. Ostrach
2:00 P.M.	Proposed Relationship Between NASA Researchers and External Experts (requested at last meeting)	Dr. Ross
3:00 P.M.	BCPR Presentation (requested at last meeting)	Dr. Fogleman
4:00 P.M.	NSBRI Presentation (requested at last meeting)	Dr. Sutton
5:00 P.M.	ISS Exploration Research Planning Status	Mr. Ahlf
6:00 P.M.	Adjourn	

Friday, May 21

8:00 A.M.	International Space Station Utilization Update	Dr. Thomas
9:30 A.M.	2008 Lunar Orbiter Status	Dr. Lomax
10:00 A.M.	CEV Presentation	Mr. Lyles
11:00 A.M.	Review of Issues, Findings, and Recommendations	Dr. Baldwin
12:00 P.M.	Adjourn	

Appendix C

Attendees

Mary Musgrave/University of Connecticut
Jeffrey S. Borer/Cornell University
Tim Anderson/University of Florida
Ken Baldwin/University of California at Irvine
Ron Merrell/UCU
Emily Holton/ NASA-Ames
Louis Ostrach/NASA
Charles Fuller/UCD
Diana Jennings/Marine Biology Laboratory
John-David Bartoe (sp?) /NASA-Johnson Space Center
Amy Kronenberg/Lawrence Berkeley Laboratories
Ray Askew/Texas A&M
Michael Duke/Colorado School of Mines
Volker Kern/NASA HQ
Howard Ross/NASA HQ
Stephen Day/IVA Ltd.
Nicholas Bigelow/University of Rochester
Guy Fogleman/NASA HQ
Rebecca Gilchrist/NASA HQ/GG
Tom Daley/US Navy
Mayra Montrose/NASA/AS
Andrew Falcon/NASA/G
Eugenia Wang/University of Louisville
Jeffrey Sutton/NSBRI
Katie Spear/NASA
Gerard Faeth/University of Michigan
Peter Ahlf/NASA HQ
Patricia Russell/USRA/NIAC
Bernard Seery/NASA
Chris Shenk (sp?)/House Science Committee
Richard Obermann/House Science Committee
Dennis McSweeney/NASA
David Jarrett/NASA
Stephen McGinley/NASA/L
Justin Tilson (sp?)/NASA HQ
Elizabeth Gonzalez/NASA/U
Stephen Papagiotas/NASA HQ/U
Mary Kicza/NASA HQ/U
Lisa Guerra/NASA HQ/U
Chuck Sawin/NASA JSC
Patricia Currier/NASA HQ
Brad Carpenter/NASA HQ/UG

Terri Lomax/NASA HQ/U
Roger Crouch/NASA/U
Dan Thomas/JSC
Frank Schewengerdt/NASA/U
Diana Jennings/MBL
Donna Shortz/NASA
Garry Lyles/NASA/T

Appendix D

Materials presented

1. *Ethics Briefing for Special Government Employees Serving on NASA Advisory Committees,* Ellen Gilchrist
2. *Status of February 12-13, 2004 Recommendations, Report to the BPRAC,* Louis Ostrach, Ph.D.
3. *Office of Biological and Physical Research: Program Overview to the BPRAC,* Mary Kicza.
4. *Exploration Product Lines: Presentation to the BPRAC,* Bernard D. Seery
5. *Office of Biological and Physical Research: Design Path for Rodent Habitat,* Louis Ostrach, Ph.D.
6. *Research Prioritization Transition Plan/New Relationship Between NASA Researchers and External Experts,* presented by Howard Ross, Ph.D.
7. *Bioastronautics Critical Path Roadmap,* presented by Guy Fogleman, Ph.D.
8. *National Space Biomedical Research Institute: Status Report,* Jeffrey P. Sutton, M.D., Ph.D.
9. *ISS Exploration Research Planning Status,* Peter Ahlf, Ph.D.
10. *ISS Research Status: Briefing to the BPRAC,* Donald Thomas, Ph.D.
11. *Plans for the 2008 Lunar Recon Orbiter,* Terri Lomax, Ph.D.
12. *Office of Exploration Systems Overview,* Garry Lyles

Materials distributed

1. *Bioastronautics Research Division Status Report to the BPRAC*
2. *Draft copy of Bioastronautics Critical Path Roadmap*
3. *Summary of Workshop on Requirements for Human Subjects in Exploration Research*
4. *Congressional Support for NASA's Vision for Exploration*
5. *NSBRI Selected Research Projects*
6. *A Giant Leap, But a Shaky Foothold;* Los Angeles Times, May 16, 2004
7. *Meeting Report: Animal Research in Support of Human Space Exploration, Workshop/NAS/Woods Hole, MA*

Appendix E
BIOLOGICAL AND PHYSICAL RESEARCH ADVISORY COMMITTEE (BPRAC)

Dr. Kenneth M. Baldwin **(Chair)**
Professor
Department of Physiology and Biophysics
College of Medicine at Irvine
University of California
D340 Medical Science, Bldg. 1
Irvine, CA 92697
Tel: 949-824-7192
FAX: 949-824-8540
Email: kmbaldwi@uci.edu

Dr. Timothy J. Anderson
University of Florida
300 Weil Hall
Gainesville, FL 32611-6550
Tel: 352-392-0946
FAX: 352-392-9673
tim@ufl.edu

Dr. Nicholas Bigelow
DuBridge Professor of Physics
The University of Rochester
Department of Physics and Astronomy
Rochester, NY 14627-0011
Tel: 585-275-8549
FAX: 585-275-8527
Email: nbig@lle.rochester.edu

Ms. Linda Billings
SETI Institute
3654 Vacation Lane
Arlington, VA 22207
Tel: 202-479-4311
703-528-2334
FAX: 202-484-8251
Email: lbillings@seti.org

Dr. Jeffrey Borer
The Gladys and Rolan Harriman Professor
of Cardiovascular Medicine
Cornell University Center
525 East 68th Street, Room F467
New York, NY 10021
Tel: 212-746-4646
FAX: 212-746-8448
Email: memontal@med.cornell.edu

Mr. Thomas J. Daley
Technical Specialist
Code 9211, Carderock Division
Philadelphia Naval Business Center
Philadelphia, PA 19112-5083
Tel: 215-897-7224
FAX: 215-897-7771
Email: daleytj@nswccd.navy.mil

Mr. Stephen Day
International Ventures Associates
5333 Potomac Avenue, NW
Washington, DC 20016
Tel: 301-571-9426
FAX: 301-564-9619
202-363-9885
Email: ssday1@aol.com

Dr. Michael Duke
Center for Commercial Applications of
Combustion in Space
Colorado School of Mines
1500 Illinois Street
Golden, Colorado 80401
Tel: 303-384-2096
FAX:
Email: mduke@mines.edu

Dr. Gerard M. Faeth
Arthur B. Modine Professor of Aerospace Eng. and Head of the Gas Dynamics Laboratories
Department of Aerospace Engineering
3000 FXB Building
1320 Beal Avenue
University of Michigan
Ann Arbor, MI 48109-2140
Tel: 734-764-7202
FAX: 734-936-0106
Email: gmfaeth@umich.edu

Dr. Charles A. Fuller
Section of NPB
189 Briggs Hall
University of California
Davis, CA 95616-8519
Tel: 530-752-2979
FAX:
Email: cafuller@ucdavis.edu

Dr. Leroy P. Gross
President
InoMedic Inc
6 Creekside Place
Hampton, VA 23669
Tel: 757-851-5101
FAX: 757-851-5133
Email: lpgross@inomedic.com

Dr. Amy Kronenberg
Lawrence Berkeley National Laboratory
One Cyclotron Road, Bldg. 70a-1118
Berkeley, CA 94720
Tel: 510-486-6449
FAX: 510-486-4475
A_Kronenberg@lbl.gov

Dr. Richard T. Lahey , Jr.
The Edward E. Hood Professor of Engineering
Rensselaer Polytechnic Institute
110 8th Street
Troy, New York 12180-3590
Tel: 518-276-6614
FAX: 518-276-3055
laheyr@rpi.edu

Dr. Ronald C. Merrell
Virginia Commonwealth University
Professor of Surgery
1101 E Marshall Street #8-015
PO Box 984480
Richmond, VA 23298
Tel: 804-827-1020
FAX: 804-827-1029
Email: ronald.merrell@vcu.edu
Email: deborah.rice@vcu.edu

Dr. Mary Musgrave
Professor and Head
Department of Plant Science, U-67
1376 Storrs Road
University of Connecticut
Storrs, CT 06269-4067
Tel: 860-486-2924
FAX: 860-486-0682
Email: mary.musgrave@uconn.edu

Dr. Charles M. Oman
Director, Department of Aeronautics & Astronautics
Center for Space Research
Man Vehicle Laboratory, Building 37-219
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, MA 02139
Tel: 617-253-7508
FAX: 617-258-8111
Email: cmo@space.mit.edu

Dr. Eugenia Wang
Department of Biochemistry and Molecular Biology
University of Louisville School of Medicine
Louisville, KY 40292
Tel: 502-852-2556
FAX:
Email: eugenia.wang@louisville.edu

Executive Secretary

Dr. Louis Ostrach
NASA Headquarters
Mail Code UF
Office of Biological and Physical Research
Washington, DC 20546-0001
Tel: 202-358-0870
FAX: 202-358-4168
Email: louis.h.ostrach@nasa.gov

Advisory Committee Specialist

Ms. Beth Craig
NASA Headquarters
Mail Code UG
Office of Biological and Physical Research
Washington, DC 20546-0001
Tel: 202-358-1601
FAX: 202-358-3091
Email: Beth.Craig@nasa.gov